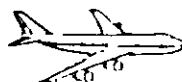


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FUEL FLOW INDICATING SYSTEM - DESCRIPTION AND OPERATION

General

- A. The fuel flow indicating system measures the instantaneous fuel flow rate and the fuel consumed by each engine and provides continuous visual indication of both values on indicators in the flight compartment. The system consists of a servo fuel flow rate indicator, a synchronous motor type fuel used indicator, and a fuel flow transmitter for each engine; an electronic module, a vertical scale fuel flow rate indicator, and a fuel used indicator reset switch for the four engine system. (See figures 1, 2, 3 and 4.) Power for the system is 115 volts ac supplied from the main power circuit breaker panel P6 ac bus No. 1 for engine 1, ac bus No. 2 for engine 2, ac bus No. 3 for engine No. 3, and ac bus No. 4 for engine 4. Power for the fuel used indicator reset operation is 28 volts dc from main power circuit breaker panel P6 dc standby bus.
 - B. Fuel to each engine is passed through a fuel flow transmitter that converts the fuel flow rate to electrical pulse signals. The pulse signals are processed in the electronic module and transmitted to the indicators. The vertical scale fuel flow rate indicator provides calibrated tape readouts of instantaneous fuel flow rate in pounds per hour. The fuel flow rate indicator provides printer and digital readouts of instantaneous fuel flow rate in pounds per hour. The fuel used indicator, provides digital readout of fuel consumed per engine.
 - C. Fuel flow rate and fuel used indicators that register consumption with engines shutdown on the ground can be ignored. Fuel movement in these instances is usually caused by warm fuel or gas bubbles rising within the system.
2. Fuel Flow Transmitter (Fig. 1)
 - A. The fuel flow transmitter measures the fuel flow rate to each engine. It consists of a rotating measurement assembly, a synchronous motor, two pickoff coils, and a transmitter body. The rotating measurement assembly is comprised of a multivane impeller, a drum that is spring coupled to the impeller, and four powerful magnets. Two of the magnets are located on the circumference of the drum 180 degrees apart; the other two are located on the circumference of the impeller, also 180 degrees apart. The two pickoff coils are mounted on the transmitter body. The transmitter is located on the right side of the engine and is installed in line between the fuel control and the fuel oil cooler.
 3. Fuel Flow Electronic Module (Fig. 2)
 - A. The fuel flow electronic module processes pulses from the individual engine fuel flow transmitters and provides electrical output signals that are compatible with the fuel flow rate and fuel used indicators. The electronic module is composed of four independent channels and a self-test module housed in a three-eighths short ATR case. Each channel contains a replaceable electronic card. The card consists of a power supply, a pulse converter section, a fuel flow rate section, a fuel used section, and a motor phase and drive section.

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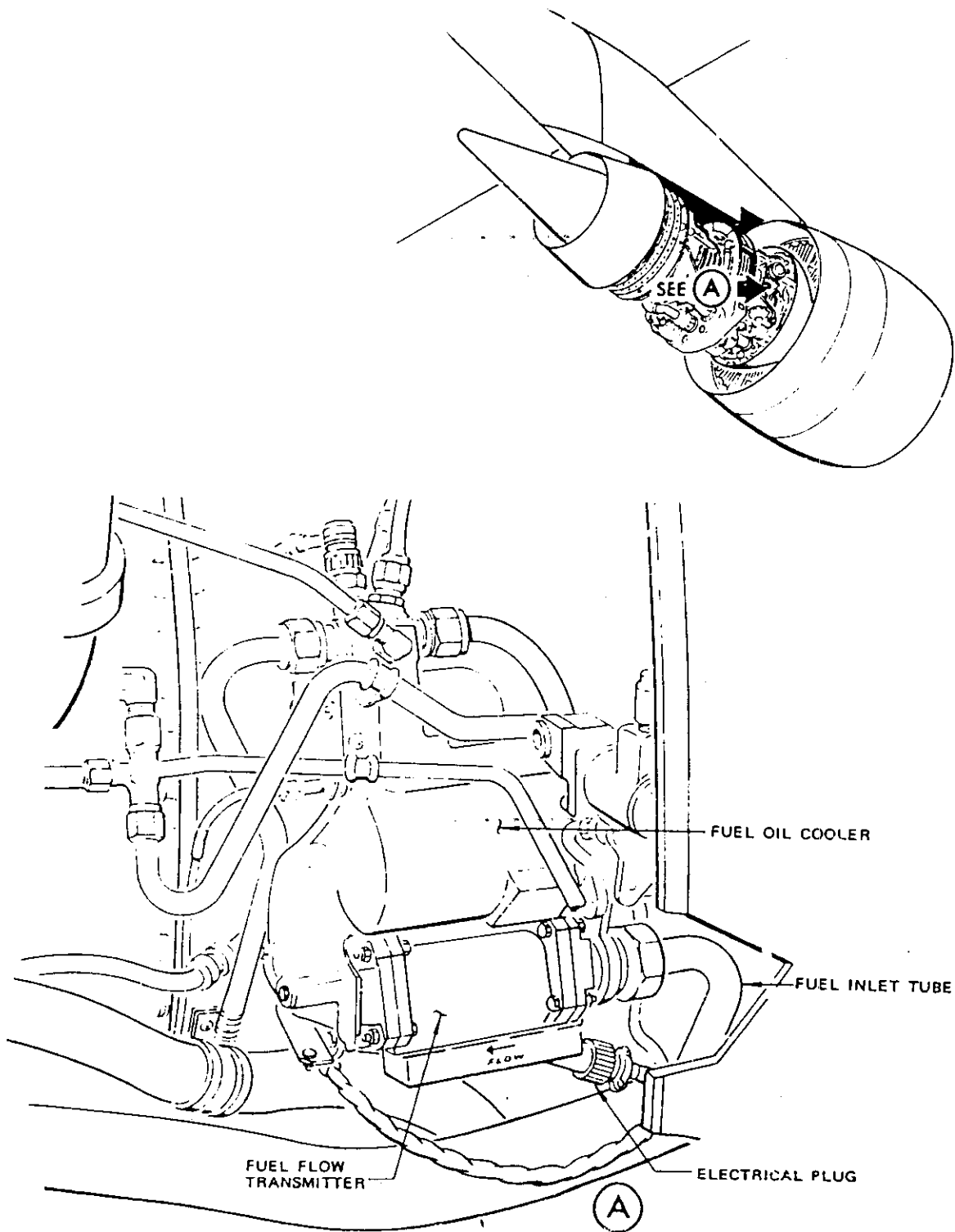
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Fuel Flow Transmitter Location
 Figure 1

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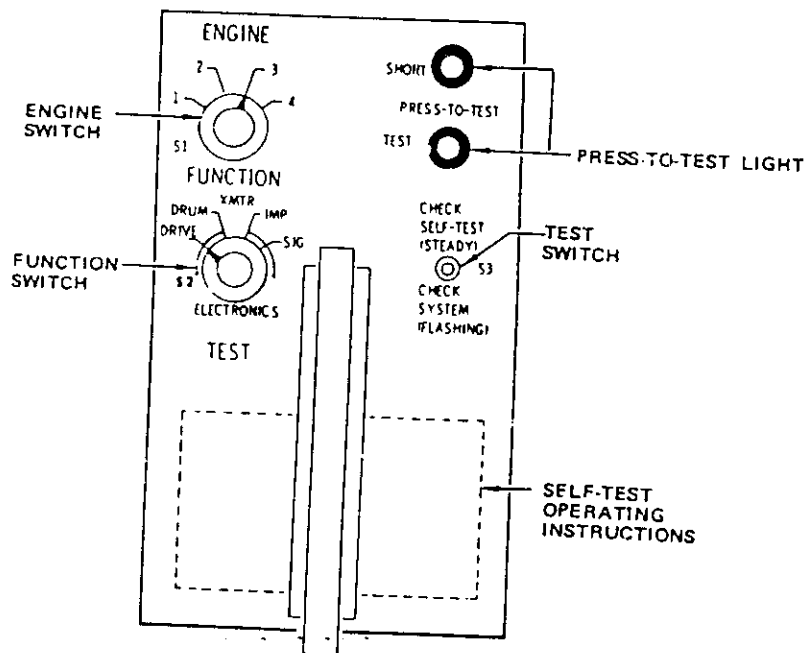
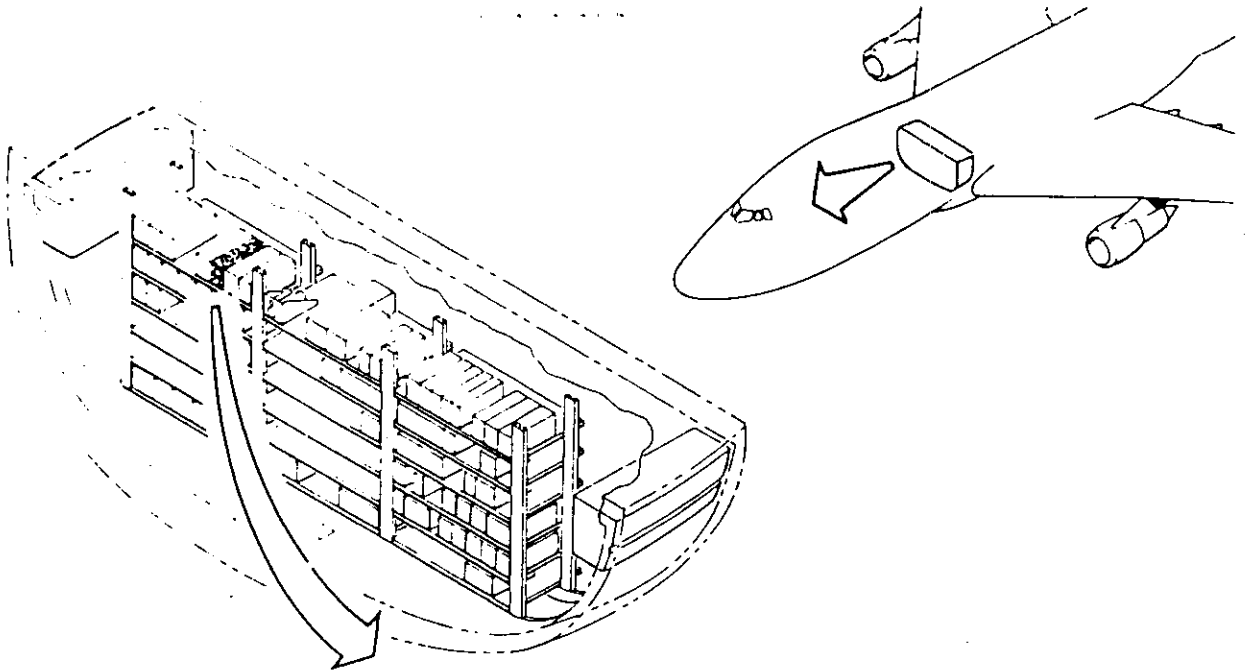
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Fuel Flow Electronic Module Location
Figure 2

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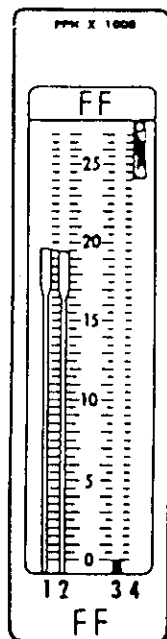
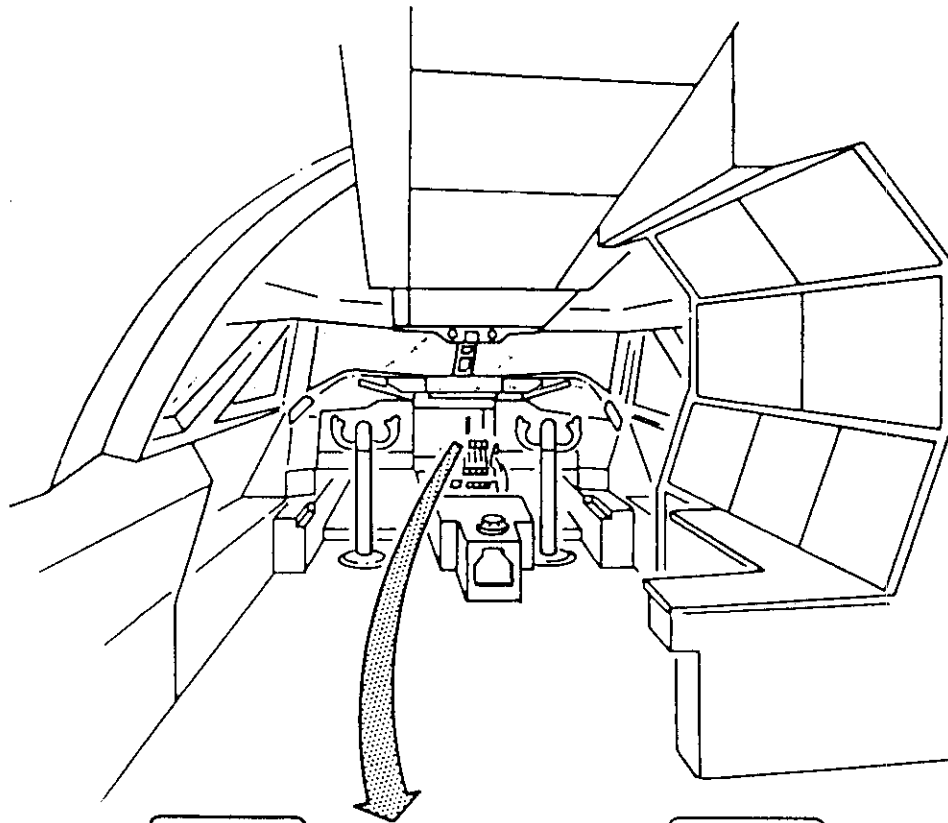
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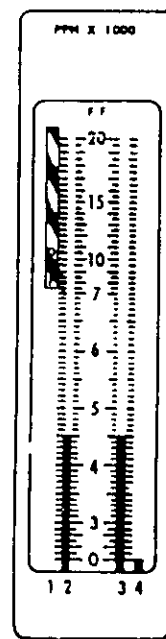
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VERTICAL
SCALE
FUEL FLOW
RATE
INDICATOR
(0-25PPH)



VERTICAL
SCALE
FUEL FLOW
RATE
INDICATOR
(0-20PPH)

PILOTS' CENTER INSTRUMENT PANEL

Vertical Scale Fuel Flow Rate Indicator Location
Figure 3

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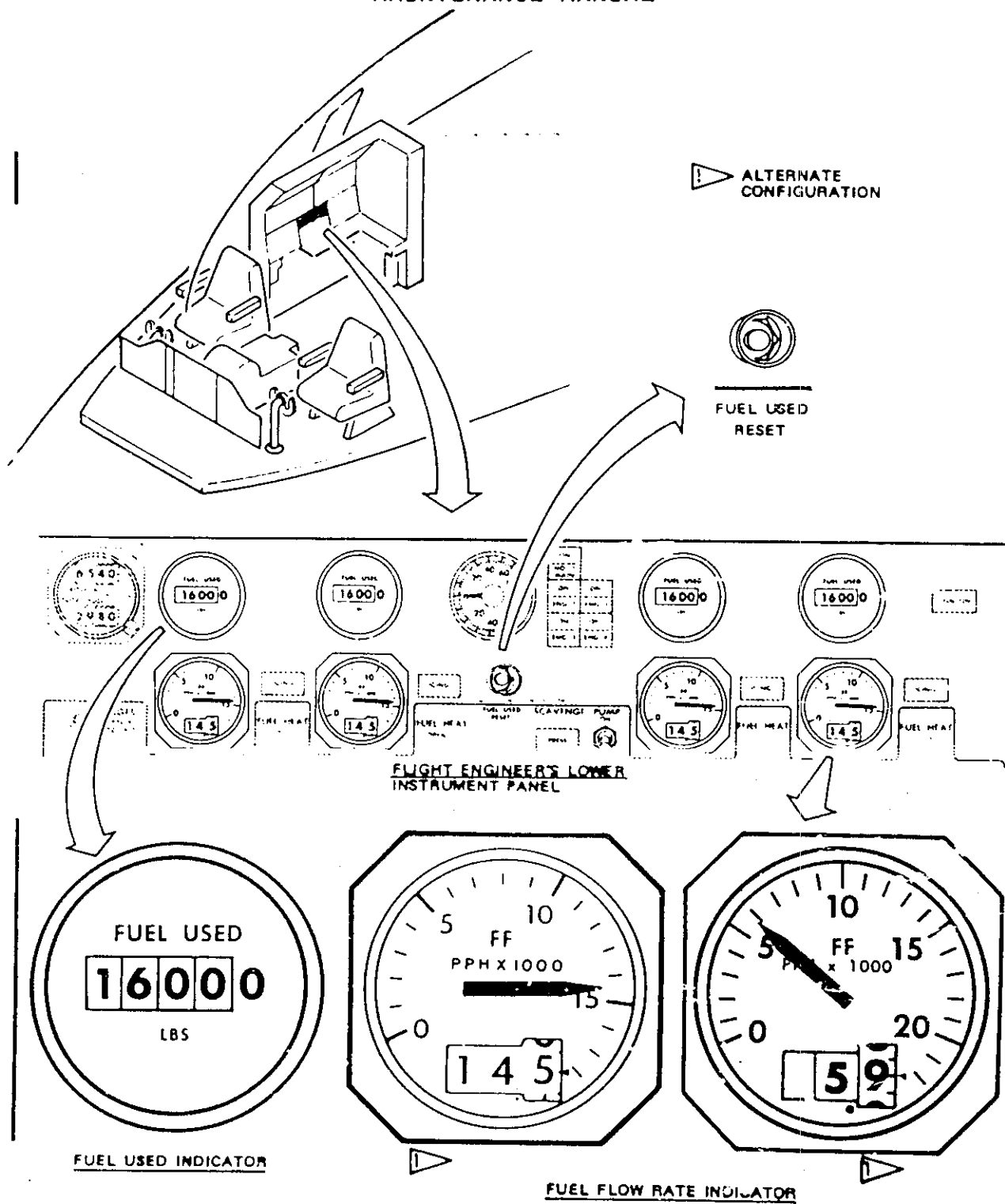
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Fuel Flow Rate and Fuel Used Indicator and Reset Location
Figure 4

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- B. The power supply consists of a rectifier circuit and a standardizing clock oscillator. The pulse converter consists of a pulse shaper, a bistable circuit and an inhibitor circuit. The fuel flow rate section is an averaging filter circuit consisting of a clamp circuit and a ripple filter. The fuel used section is a time-interval to frequency converter circuit. It consists of a gate circuit and a computing divider. The motor phase and drive section consists of a crystal clock divider, motor phase timer, and motor drive switching circuit.
 - C. The self-test module is provided to locate faults in the transmitter, in the electronic module, in the fuel flow rate indicator, and in the fuel used indicator. The self-test module consists of two lamp drivers, level detector, monostable multivibrator, engine selector switch, function selector switch, test switch, and press-to-test neon lamps. Two neon lamps, one for transmitter motor short circuit indication and one for test indication, are replaceable without disassembling the electronic module.
 - D. Fuel flow electronic module is located in the main equipment center on right shelf E3-1. Self-test controls are accessible without removing the electronic module from the shelf.
4. Vertical Scale Fuel Flow Rate Indicator (See figure 3.)
- A. The vertical scale fuel flow rate indicator provides calibrated tape readouts of the instantaneous fuel flow rate to the engine in pounds per hour. The indicator consists of four channels, one for each engine, dual integral lighting systems, and a case. The indicator is not hermetically sealed. Each channel is comprised of a power supply, measuring circuit, servomotor, gear train, moving calibrated tape and fixed graduated scale. Each tape drive mechanism is equipped with upper and lower limit stops. Each indicator channel is independent and incorporates its own failure indication. Malfunction of any one channel does not affect the operation of other channels. The tape is driven to OFF position when motor electrical failure, loss of primary power, or signal loss occurs. The vertical scale fuel flow rate indicator is located on pilots' center instrument panel.
5. Round Dial Fuel Flow Rate Indicator (Fig. 4)

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- A. The fuel flow rate indicator provides pointer and digital readouts of instantaneous fuel flow rate to the engine in pounds per hour (pph). The indicator is basically a position servo type dc voltmeter, using a potentiometer as the position feedback element. The indicator consists of a power supply, measuring circuit, potentiometer, amplifier integral integrity monitor, servomotor, gear train, coarse indication pointer, graduated dial face, a numerical counter, integral lights and a case. The indicator is not hermetically sealed. Electronic components are solid-state and are mounted on removable circuit boards. The counter consists of three rotating drums with numerals. Downward rotation of drum indicates fuel flow increase. The indicator incorporates a failure warning flag which drops in front of counter numerals when power is not received, when voltage is too low, or when a sustained mechanical malfunction occurs. The integral lights are replaceable without disassembling the indicator. Four indicators, one for each engine, are located on flight engineer's lower instrument panel.
6. Fuel Used Indicator (See figure 4.)
- A. The fuel used indicator provides a continuous digital readout of the accumulative fuel consumption by each engine in pounds. The indicator consists of a power supply, filter circuit, trigger circuit, gate circuit reset circuit, stepper motor, gear train, mechanical numerical counter, integral lights and a case. The indicator is not hermetically sealed. Electronic components are solid-state and are mounted on removable circuit boards. The numerical counter consists of four rotating drums with numerals. A stationary 0 is marked on indicator dial face to complete a five digit readout. Downward rotation of drums indicate consumption increase. Four indicators, one for each engine, are located on flight engineer's lower instrument panel.
7. Operation (See figure 5.)
- A. Functional Description
- (1) The fuel flow indicating system is operative when 115 volt ac power is supplied to the indicators and to individual channel power supplies in the electronic module. Each channel power supply provides various regulated dc voltages to the channel components and 40 volts dc to the motor drive switching circuit. In the motor phase and drive section, low frequency signals from the crystal clock divider drive the motor phase timer and provide timing signals to the motor drive switching circuit. These timing signals trigger the switching circuit and generate two resultant pulse train voltages lagging each other by 90 degrees. The 40 volt dc pulse train voltages are supplied to and actuate the transmitter synchronous motor. In addition, the reference supply circuit provides 5 volt dc reference signal to the clamp circuit and the fuel flow rate indicator. With 28 volt dc power supplied to the fuel used reset circuit, the circuit is operational when the reset switch is actuated.

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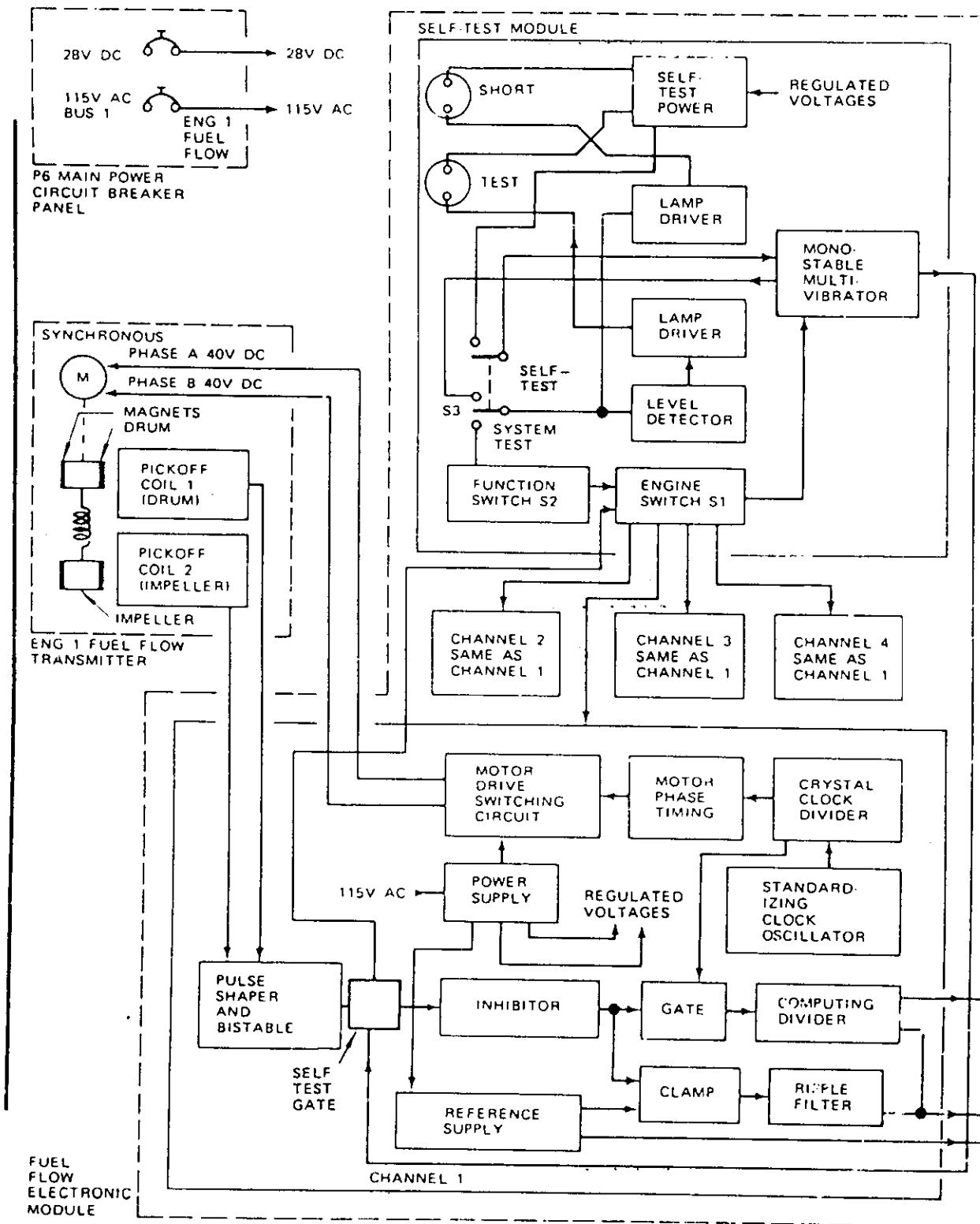
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Fuel Flow Indicating System Block Diagram
Figure 5 (Sheet 1)

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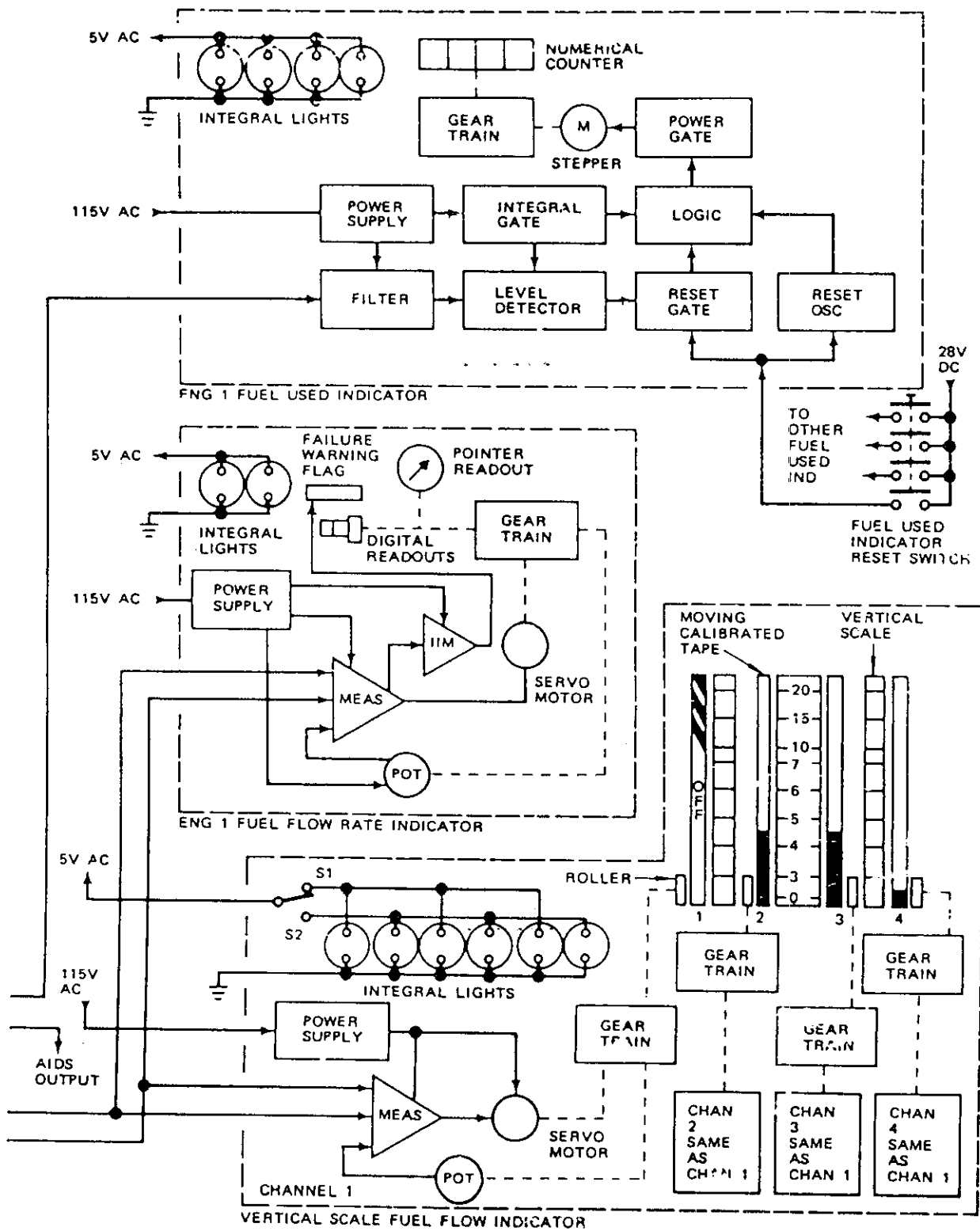
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Fuel Flow Indicating System Block Diagram
Figure 5 (Sheet 2)

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- (2) Fuel flowing from the fuel control to the pressurizing and dump valve passes through the fuel flow transmitter. The transmitter operates on an angular momentum/rotor torque principle. The transmitter measurement assembly is driven by the synchronous motor at a constant speed of 100 rpm. As each magnet (on drum and impeller) is rotating past its respective pickoff coil, an electrical pulse is induced in the coil. Fuel entering the transmitter first passes through radial straightening vanes to remove swirl and stabilize flow. The stabilized flow then passes through the annular space in the measurement assembly and imparts angular deflection of the impeller relative to the drum. This results in a time displacement of the impeller pulses to the drum pulses. The time difference between the pulse induced in pickoff coil No. 1 by magnet No. 1 (on drum) and the pulse induced in pickoff coil No. 2 by magnet No. 2 (on impeller) is a measure of the mass fuel flow rate. The greater the mass flow rate, the larger the deflection of the impeller relative to the drum and the larger the time displacement between corresponding pulses. With no fuel passing through the transmitter, the time displacement between the two pulses is zero. The transmitter output pulses from the two pickoff coils are supplied to the electronic module.
- (3) Each transmitter operates a separate channel in the electronic module. Pulse signals from the transmitter are filtered and amplified by the pulse shaper then fed to the bistable circuit. Each drum pulse triggers the bistable on, while each impeller pulse triggers it off. This generates a resultant rectangular pulse train signal. The pulse width of the rectangular pulse is equal to the time displacement between the impeller pulse and the drum pulse, and is proportional to mass fuel flow rate. The signals from the bistable circuit are fed to an inhibitor circuit. This circuit imposes a threshold flow rate below which all signals are inhibited. Only at flow rates above the threshold, the inhibitor provides output signals. The output signals then are supplied to the fuel flow rate section and to the fuel used section on the electronics card.
- (4) In the fuel flow rate section of the cards, signals from the inhibitor drive the clamp circuit and generate a replica of the data pulse train. The amplitudes of the pulse train are clamped to a precise positive voltage during pulse width and to zero at all other times. The result is a pulse train signal with the average voltage proportional to the product of the flow rate and the positive supply voltage. The signal then passes through a ripple filter, and provides a ripple-free dc output signal to the fuel flow rate indicator.

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- (5) In the fuel used section of the cards, the data pulse train signals from the inhibitor and the bistable and high frequency pulses from the crystal clock divider drive the gate of fuel used circuit. The data pulse triggers the gate circuit on at the beginning of the data pulse width and triggers the gate circuit off at the end of the data pulse, allowing the crystal clock frequency to pass on to the computing divider only during the pulse width period. The output average frequency (average number of pulses per second) is divided by a computing divider, which is a multistate binary counter, to a low frequency pulse train and supplied to the fuel used indicator. Each pulse represents 10 pounds of fuel used.
- (6) The dc output signals from the fuel flow rate electronics section are supplied to the vertical scale fuel flow rate indicator channel and to the fuel flow rate indicator. In each channel, the dc signals and the corresponding feedback potentiometer signals are supplied to the servosystem measuring circuit. The differential of the two signals (error signals) is amplified and supplied to the servomotor control windings. The servomotor is energized and drives the moving tape via the gear train. The potentiometer, also driven by the gear train, provides feedback signals to the servomotor until the error signals are nulled and the system is again in equilibrium. The four fuel flow rate readouts are displayed in pounds per hour by calibrated tapes against fixed vertical scales. When a channel malfunction occurs due to electrical failure in the system, that channel tape will drive to OFF position. When the malfunction is corrected, the channel automatically resets.
- (7) In the fuel flow rate indicator, the dc signals and the corresponding feedback potentiometer signals are supplied to servosystem amplifier. The differential of the two signals (error signals) is amplified and supplied to the servomotor control windings. The servomotor is energized and drives the pointer and counter via the gear train. The potentiometer, also driven by the gear train, provides feedback signals to the servomotor until the error signals are nulled and the system is again in equilibrium. The indicator displays the instantaneous fuel flow rate in pointer and digital form. With the engines set to takeoff thrust, all the fuel flow rate indicator pointers should point to 3 o'clock position. The integral integrity monitor circuit provides power to the failure warning flag actuating coil. If a circuit malfunction occurs, the coil is de-energized and the failure warning flag drops in front of that circuit indicator counter numerals and partially covers the numerals. Pointer and counter may remain at the last indication before the failure occurred. When the circuit is corrected, the actuating coil is energized and the failure warning flag automatically resets.

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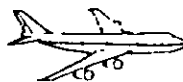
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- (8) The low frequency pulse train output signals from fuel used electronics section are supplied to the fuel used indicator. Each pulse, representing 10 pounds of fuel, actuates the stepper motor in the fuel used indicator. When actuated by a pulse, the stepper motor rotates through 90 degrees and drives the indicator numerical counter one digit in advance. The fuel used indicator thus displays the accumulative fuel used readout.
- (9) The fuel used indicators are reset when the reset switch, located on the flight engineer's lower instrument panel, is actuated. The actuation of the switch supplied 28 volt dc power to each indicator stepper motor reverse mode. The stepper motor drives the numerical counter in reverse until the indicator shows zero.
- (10) During normal operation, the self-test module is isolated from the indicating system. Any fault of the self-test module will not affect the normal operation of the system. When a particular engine system is under test, signals from the transmitter or the corresponding channel electronics card may be selected and routed to the level detector. The level detector provides an output signal only when the input signals are within predetermined limits. The output signals from the level detector are supplied to the lamp driver circuit, which in turn, drives the test indication neon lamp. If the signals are from the transmitter drum or impeller or the motor phase and drive section, the lamps will flash approximately at the rate of 3 times per second to indicate that the component under test is operating properly. If the signals are from the fuel flow rate section or fuel used section, the lamp will flash approximately once every 3 seconds. Signals simulating a flow rate of 12,000 μ ph are provided to the fuel flow rate indicator and fuel used indicator during self-test, to check proper operation of the indicators. If transmitter motor power supply or cable is shorted, the short circuit indication lamp becomes illuminated and automatically extinguished when fault is removed. In addition, the self-test module operation can be verified. To do this, the power supply frequency signals are supplied through a monostable multivibrator to the level detector. Output signals from the level detector, also supplied to the lamp driver, energize the neon lamps. If the module circuit is operating properly, both lamps will be steady on during the test.
- (11) The instrument dial illumination lamps are supplied 0 to 5 volt ac power as part of the light circuit that controls all lightplates and integral instrument lamps for that panel. Refer to 33-11-00, Pilots' Panel Lights, for description of the vertical scale fuel flow rate indicator illumination. Refer to 33-12-00, Flight Engineer's Panel Lights for description of the fuel flow rate and the fuel used indicator illumination. The vertical scale fuel flow rate indicator contains dual integral light systems. If one system fails, the other system can be connected to the panel light power source by repositioning a switch on the back of the indicator.

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